

may be moved up and down relative to a cylinder due to the expansion and contraction of a material contained within the cylinder. The material contained within the cylinder may be a fluid, a gel, a crystal, or any material that exhibits a change in volume due to an applied stimulus. For example, when using a material that exhibits a volume change in response to an applied electric field, a piston is move a distance proportional to the amount of current applied.

[0019] Another way in which the haptel could be actuated is through the use of hydraulics to move each haptel element. Alternatively, another method is to create a magnetic current for the haptel by running a wire around a region of the haptel to create a coil and move the haptel element by charging the coil. Yet another way of actuating the haptel element could be through the use of small motors. Many configurations of drive mechanisms are possible for the haptel element. The distance that the haptel element may travel is a function of a particular design and is not limited by the present invention. Distances on the order of four to eight centimeters are contemplated for certain applications, however, much larger or smaller distances might be used depending on the values of the haptic data that the user wished to display.

[0020] Temperature might be displayed on the haptic element by the use of thermoelectric heating or cooling devices to display the temperature of a surface. While the haptic element has been depicted as a pin, in FIG. 3, the present invention is not so limited. Haptic elements may be configured as desired according to the data the user wishes to display. In some instances the haptic element may be configured as a pad, which is sensitive to pressure. The haptel may be configured in many embodiments without departing from the spirit of the present invention.

[0021] In another embodiment, of the present invention, the haptel may be configured to provide both input and output functions within a single device. With reference to FIG. 4, input/output (I/O) haptel 40 is connected via signal path 10 with I/O haptel 42. An I/O haptel combines the ability to both display haptic data and input haptic data within a given device. By way of illustration, haptic data in the form of force is indicated by the length of the arrows used in FIG. 4; input force 40a is larger than output force 42a.

[0022] User 1 pushes on I/O haptel 40, applying input force 40a to haptel element 40b. Signal 40c is generated in response to input force 40a. Signal 40c arrives at I/O haptel 42, by way of signal path 10. At I/O haptel 42, force 40a is reproduced in response to signal 40c and is imparted to haptel element 42b.

[0023] Similarly user 2 pushes on I/O haptel 42 by applying force 42a to haptel element 42b. Signal 42c is generated in response to input force 42a. Signal 42c arrives at I/O haptel 40 by way of signal path 10. At I/O haptel 40, force 42a is reproduced in response to signal 42c and is imparted to haptel element 40b.

[0024] In real time, user 1 pushes against force 42a. Force 42a is displayed on I/O haptel 40 while being simultaneously generated by user 2 with I/O haptel 42. Thus, user 1 experiences the virtual "push" of user 2 on I/O haptel 40. Since force 40a has been arbitrarily chosen to be larger than force 42a, user 1 will be able to overcome the push of user 2, thereby moving haptel element 40b down in the direction indicated by input force 40a.

[0025] The corresponding display of haptic data will occur on I/O haptel 42. User 2 will feel the virtual "push" manifested by input force 40a as input force 40a is displayed on I/O haptel 42. Force 42a imparted by user 2 to haptel element 42b is smaller than force 40a displayed on I/O haptel 42, therefore user2 will be overcome by input force 40a as haptel element 42b is moved up in the direction indicated by input force 40a on I/O haptel 42.

[0026] In another embodiment, of the present invention, a group of haptels may be placed together to create an array of haptels which define a surface or a geometric shape. With reference to FIG. 5, a user is shown feeling the surface of an array of haptels. User's hand 54 is shown reading the haptic data displayed on array 50. A user can see and feel the surface of array 50. The surface of a haptic array can display any form of haptic data desired. The configuration of the array of haptels may take on any desired two or three-dimensional shape.

[0027] For example, a haptel array could be configured as a ball that a user would squeeze or a glove into which a user would insert his hand that the haptel array would then squeeze, in this way users could virtually hold hands. Many configurations of a haptel array are possible; those that are mentioned in this detailed description are but a few and are not to be construed as limitations on the configurations that are possible.

[0028] The previous discussion, directed to FIG. 4, concerned an I/O haptel configured to read and display force. However I/O haptels may be configured as required to read and display other forms of haptic data. For example, an array of haptels forming a surface could change relative to the dance of a virus in a scanning electron microscope or the discrete gray scale values in an image. Haptel elements 56 could be positioned to different levels to symbolize bold or italic text from a source of alpha numeric or graphic data, such as a web page, document, or spreadsheet. Communication between users of haptels provides a form of telepresence between the users that has not been possible with prior art communication devices.

[0029] An example of communicating telepresence is displayed in FIG. 6. With reference to FIG. 6 a real-time virtual ability to tickle a baby's foot is demonstrated. Haptel array 66 and haptel array 62 could be configured as separate input and output devices, as shown in FIG. 3, or combined I/O devices, as shown in FIG. 4. Grandmother's hand 64 inputs haptic data into haptel array 66, which is communicated to haptel array 62 via signal path 10. Baby 60 places her foot on haptel array 62 and can virtually "feel" grandmother's hand 64 tickle her foot as haptic data is displayed onto haptel array 62.

[0030] Signal path 10 may be any type of information transmission system configured to transmit and receive data. For example, haptic data may be sent over the Internet, or a wide area network to a user's home via a personal computer (PC). The PC unpacks the data and updates the haptel array to reflect the new information. The amount of data for a full haptel array update is approximately equivalent to an amount of data required to render a gray scale image with the same number of pixels as haptels within the haptel array. Haptels may be configured for use with the pointing device used with a PC, such as a mouse or may be configured as a separate I/O device, which only accepts haptic data. Addi-